arXiv:hep-ex/0111064v1 20 Nov 2001

IN SEARCH FOR PHYSICS BEYOND THE STANDARD MODEL AT TEVATRON

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Abstract

We present the most recent results of searches for physics beyond the Standard Model using the CDF and the DØ detector at the Fermilab Tevatron Collider. All results shown correspond to analysis performed using the past 1992-1996 Fermilab Tevatron run I data (roughly 110 pb^{-1} per each experiment). In particular we report on searches for scalar top and scalar bottom particles together with other *classic* Supersymmetry analysis. Results from non Standard Model Higgs searches are also summarized.

1 Introduction

Although, at present, the Standard Model (SM) provides a remarkably successful description of known phenomena, there are plenty of aspects that we do not understand yet and that may suggest the SM to be most likely a low energy effective theory of spin-1/2 matter fermions interacting via spin-1 gauge bosons [1]. An excellent candidate to a new theory, able to describe physics at arbitrarily high energies, is Supersymmetry (SUSY). SUSY is a large class of theoretical models based on the common assumption that there exist in nature a fermion-boson symmetry. A comprehensive SUSY search is almost impossible because of the large amount of truly independent parameters. The strategy is then to search for signals suggested by particular models in which theoretical assumptions are also adopted to reduce the number of free parameters to a few. In Supersymmetry fermions can couple to a sfermion and a fermion, violating lepton and/or baryon number. To avoid this problem, a discrete multiplicative quantum number, the $\mathcal{R}$-parity was introduced [2]: $\mathcal{R} \equiv (-1)^{3B+L+2S}$. SUSY models can be constructed assuming either conservation or violation of this quantum number (RPV).

2 SUSY Searches at Tevatron Collider

2.1 Search for third generation scalar quarks

Search for scalar top squark is particularly interesting as the strong Yukawa coupling between top/stop and Higgs fields give rise to potentially large mixing effects and mass splitting. Such effects can lead the lightest top-squark mass eigenstate $\tilde{t}_1$ to be lighter than the other squarks: $m_{\tilde{t}_1} < m_{\tilde{q}}$ [3]. When a set of SUSY parameters such as A, μ and $\tan(\beta)$ [4] is suitably tuned, light bottom squarks may also occur.
Both the CDF and DØ experiments have searched for direct stop quark pair production: $p\bar{p} \to \tilde{t}_1\bar{\tilde{t}}_1$ with $\tilde{t}_1$ decaying into the following channels: $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm}$, $\tilde{t}_1 \to b\ell^+\tilde{\nu}$ [5] and $\tilde{t}_1 \to c\tilde{\chi}_1^0$ [6]. CDF has also searched for indirect stop quark production trough the top quark decay: $t \to \tilde{t}_1\tilde{\chi}^0$ with $\tilde{t}_1 \to b\chi_1^{\pm}$ [7]. Searches for direct scalar bottom production $p\bar{p} \to \tilde{b}_1\bar{\tilde{b}}_1$ with the sbottom decaying into: $\tilde{b}_1 \to b\tilde{\chi}_1^0$ have been performed from both Tevatron Experiments [6, 8]. An overview on such results can be found in [9].

2.2 Search for RPV stop decays

CDF searched for a pair produced scalar top squark decaying via non-zero $\mathcal{R}$-parity violating coupling λ'_{333} to $\tilde{t}_1 \to \tau b$ [10]. The experimental signature of this process is two τ leptons and two b quarks in the final state. Events have been selected by requiring a lepton (e or μ) from $\tau \to \ell\nu_\ell\nu_\tau$, a hadronically decaying tau lepton and two jets. The principal background processes are $Z \to \tau^+\tau^-$, W+jets, $t\bar{t}$, Drell-Yan and diboson events. We observed, combining both the muon $\tilde{t}_1\bar{\tilde{t}}_1 \to \tau^+\tau^- b\bar{b} \to \mu\tau_h b\bar{b} + X$ and the electron channel $\tilde{t}_1\bar{\tilde{t}}_1 \to \tau^+\tau^- b\bar{b} \to e\tau_h b\bar{b} + X$, that no events passed the selection cuts. This is consistent with the expected SM background of 1.92 ± 0.19 events in the electron channel and 1.13 ± 0.14 in the muon channel. A 95% *C.L.* lower limit on the stop quark mass have been set: $m_{\tilde{t}_1} > 119$ GeV/c^2, for a dominant λ'_{333} coupling. The more recent and competitive result on the lower limit of the stop mass with this signature comes from ALEPH/LEP experiment [11].

2.3 Search for MSSM neutral Higgs

The Minimal Supersymmetric Standard Model (MSSM) predicts five physical Higgs bosons: a charged pair (H^+, H^-), two CP-even scalars (h^0, H^0) and a CP-odd (A^0). CDF has searched for a neutral MSSM Higgs ϕ, where ϕ means h or H or A, produced in association with $b\bar{b}$: $p\bar{p} \to b\bar{b}\phi \to b\bar{b}b\bar{b}$. The analysis is based on on 91 pb^{-1} of data corresponding to the Run 1B multijet sample. With basic parameter choices for both the SUSY scale and the stop mixing, we obtained a 95% C.L. on the lower mass value for ϕ in a region of SUSY parameter space where: $\tan\beta > 30$. These results are summarized in Fig. 1.

2.4 Search for charged Higgs in the top quark decay

The charged Higgs particle ($H^{\pm}$) may be observed through the following top quark decay: $t \to H^+b \to \tau^+\nu b$. This process is favored over the SM one: $t \to Wb$ if $m_{H^{\pm}} < (m_t - m_H)$ in two separate $\tan(\beta)$ regions: $\tan(\beta) < 1$ and $\tan(\beta) > 70$ [12].

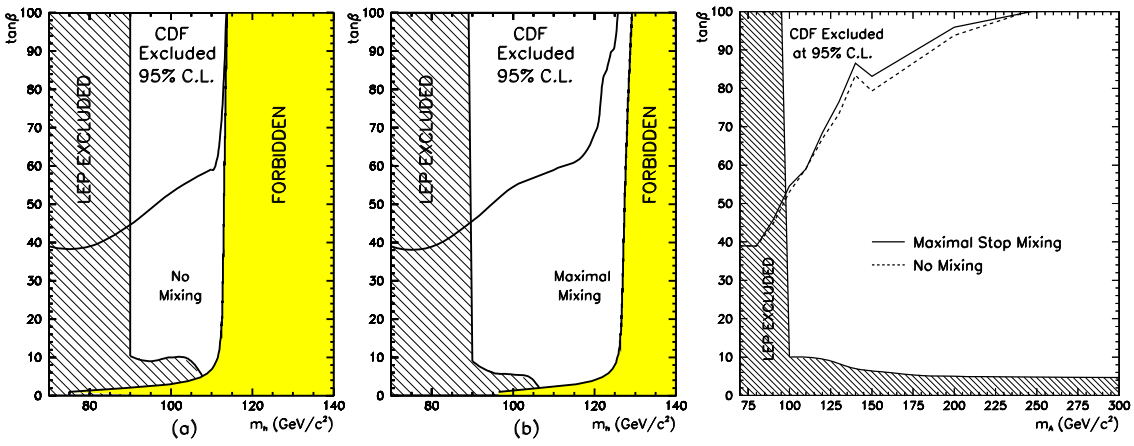

Figure 1: *(left) 95% C.L. exclusion region in the m_h versus tan(β) plane from CDF MSSM neutral Higgs search; (right) and m_A versus tan(β).*

Both CDF and DØ searched for charged Higgs. In particular the CDF direct search was performed requiring a high-P_T central lepton ($|\eta| < 1$, $p_T^\ell > 20$ GeV, $\ell = e$ or μ) as well as a central τ lepton with $p_T^\tau > 15$ GeV, 2 jets and missing transverse energy ($\not\!\!E_{\rm T}$) with significance: $S_{\not\!\!E_{\rm T}} \equiv \not\!\!E_{\rm T}/\sqrt{\sum E_T} > 3$ GeV$^{1/2}$. Better results have been obtained both from CDF and DØ performing an indirect search based on the suppression of SM $t\bar{t} \to W^+W^-b\bar{b}$ decays caused by the presence of the competitive channel $t \to H^+b$. Fig. 2 (left) show the 95% C.L. excluded region as a function of tan(β).

2.5 Search for gluino pair production using LS top events

CDF recently searched for gluino pair production using like-sign (LS) top events. The analysis have been performed using 106.1 pb^{-1} of Run I data. In the SUSY model under study the scalar top squark is not only the lightest squark but also the only one lighter than gluino and satisfy the condition: $m_t + m_{\tilde{t}_1} < m_{\tilde{g}}$. Therefore $\tilde{g} \to t\tilde{t}$ is the preferred decay channel and because of the Majorana nature of gluinos they give rise to LS top quarks from $\tilde{g}\tilde{g}$ decays. In order to search for such events CDF used the top dilepton events. The results of this search are shown in Fig. 2 (right); no mass limits have been set due to the presence of three signal events and to the inability to probe gluino masses in the region close to the top mass, where the stop mass is forced to be unreasonably light.

3 Conclusions

Tevatron Experiments performed extensive searches for physics beyond the Standard Model using the data collected during the 1992-1996 Run I. Recent results on such searches have been reported. No evidence for physics beyond the Standard Model have been found so that 95% C.L. limit have been set for the different scenarios described in the present paper. With the Run II upgrades, providing a higher acceptance and

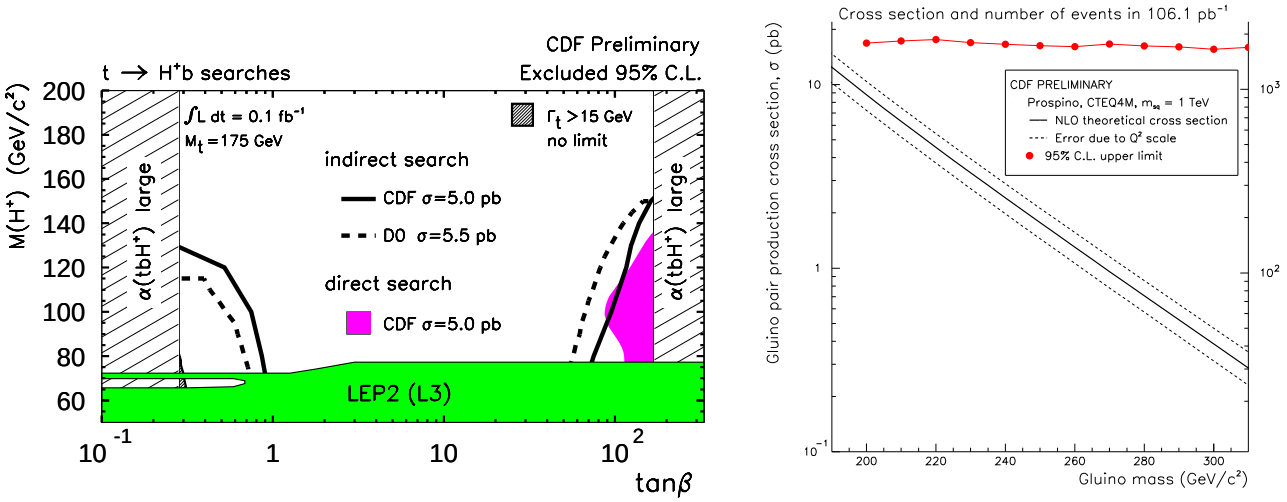

Figure 2: *(left) 95% C.L. exclusion region in the tan(β) versus $m_{H^\pm}$ plane for the charged Higgs searches from CDF and DØ; (right) 95% C.L.upper limit on the gluino production cross section as a function of $\tilde{g}$ mass using the like-sign top dilepton sample.*

higher luminosity, it will be possible to make important progress in the search for new phenomena.

4 Acknowledgments

We would like to thank the organizers of the *XIII Convegno sulla Fisica al LEP* for the excellent conference and for their kind hospitality.

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